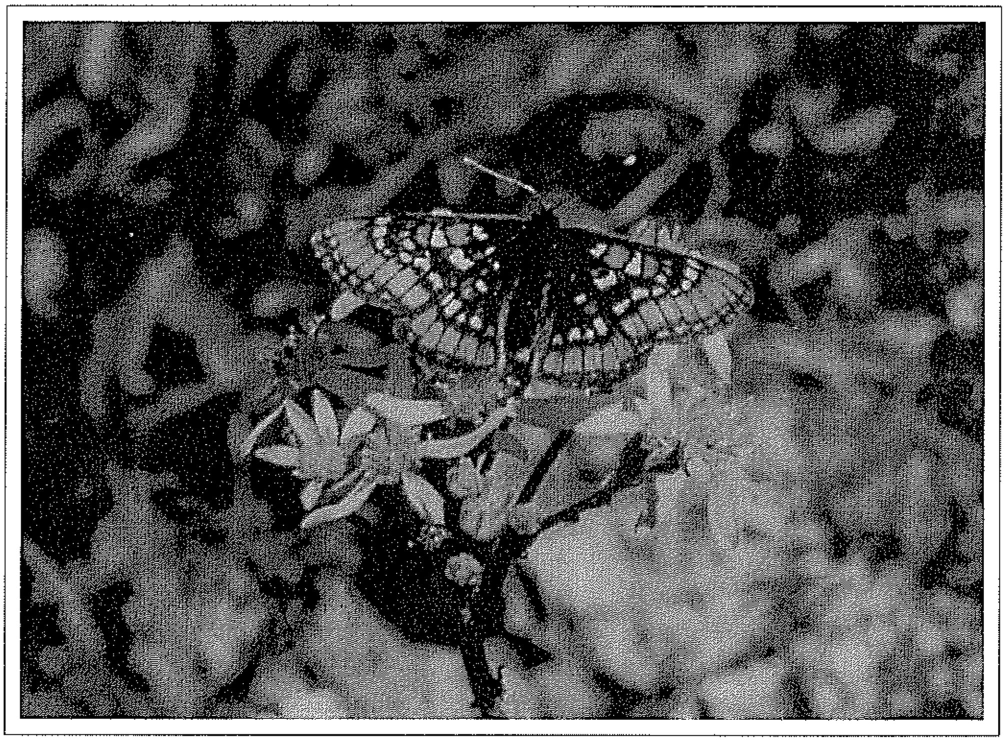
Yellowstone Science

A quarterly publication devoted to natural and cultural resources



A Mud Volcano Grows

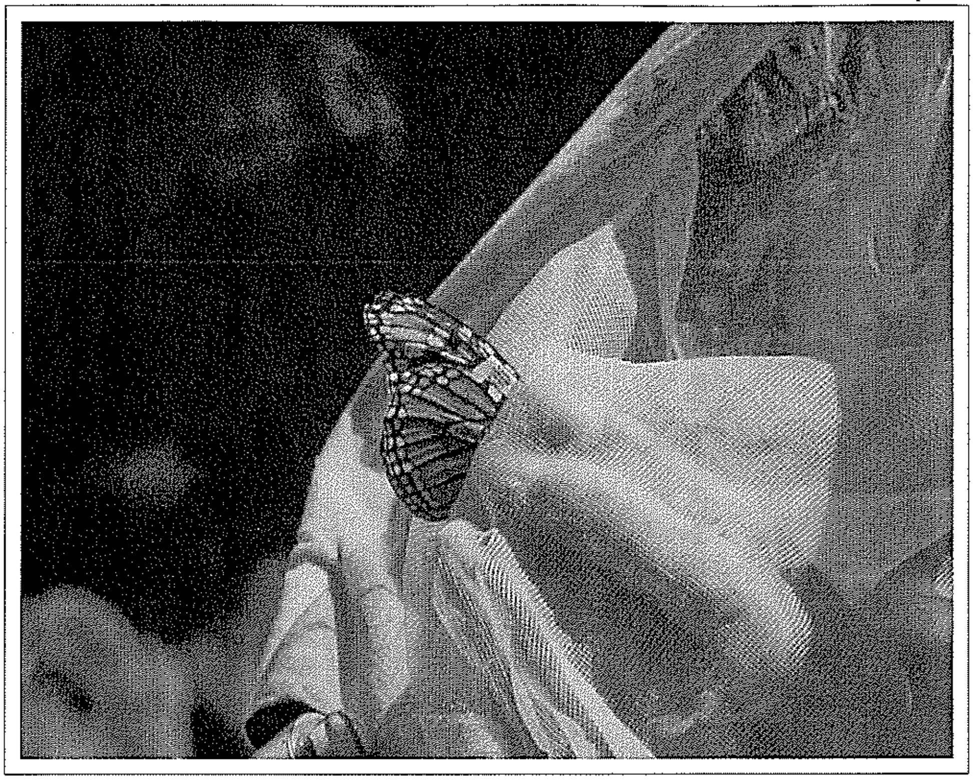
Butterflies and Biodiversity

Living with Grizzlies

Elk Migrations

Volume 4 Number 3

NPS photo



The Semantics of Science

Occasionally I hear someone referring to this magazine or other writing comment, "It's interesting, but it's not *science.*" This prompted me to mentally search back through an array of lessons from college and other life experiences for an answer to the question, "What *is* science?"

Webster refers to science as *knowledge attained through study or practice.* This includes knowledge like that discovered during Rick Hutchinson's frequent visits to Astringent Creek, and by Steve Herrero in his years of observing of grizzly bears, humans, and their relationships. *Knowledge as obtained and tested through the scientific method.* Bruce Smith's years of work on the migrations and other behaviors of the southern Yellowstone elk herd point out how researchers apply the method to answer our curiosities, and our needs, for sound information about the resources around us. Another reference calls science *a manifestation of man's will to know and to understand both himself and the world around him.* Diane Debinski's work demonstrates such a desire for understanding, appreciation, and refined prediction of how birds and butterflies use the landscape.

Science can include, but by these definitions does not require, the use of models, statistical analyses, graphical display, and mathematical equations. While reading of the Yellowstone Checkerspot, I was reminded of hearing some years ago of a man who, accompanied by his child, was fined for collecting butterflies in another national park. A judge, responding to the father's plea for what he believed was justice, admonished the park rangers for overzealousness—reminding them that a family netting butterflies was engaging in a time-honored practice for exploring nature's resources—albeit one that we no longer allow in our national parks (unless done by permitted researchers).

Rangers, surely, must protect park resources from indiscriminate collectors. And good science is most enhanced by *guided inquiry.* Yet in all of us, perhaps there remains the same curiosity and enthusiasm—guided or not—that prompts a child's desire to catch butterflies on a summer day...inquisitiveness that we may be able to vicariously appease through sharing information about a broad spectrum of scientific explorations into Yellowstone's natural and cultural resources.

That was one reason for creating *Yellowstone Science,* as envisioned by its original editor, Paul Schullery. This issue marks the passing of the editorial baton, and we wish Paul well in his new professional ventures. We revel in continuing to share information about the science undertaken in the park—and we shall interpret the term in as broad a sense as our readers and writers support. We invite you to let us know your thoughts on the semantics of science.

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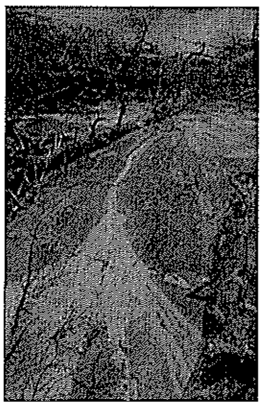
Volume 4 Number 3 Summer 1996

NPS photo Rick Hutchinson



On the cover: The Yellowstone Checkerspot, a species of concern due to its apparent population decline and specific habitat requirements. See Diane Debinski's article on butterflies and biodiversity, page 2. Cover photo by Craig Odegard.

Above: Siliceous mudflows from a recently emerged feature west of Pelican Valley. See Roderick Hutchinson's article on Astringent Creek, on page 11.

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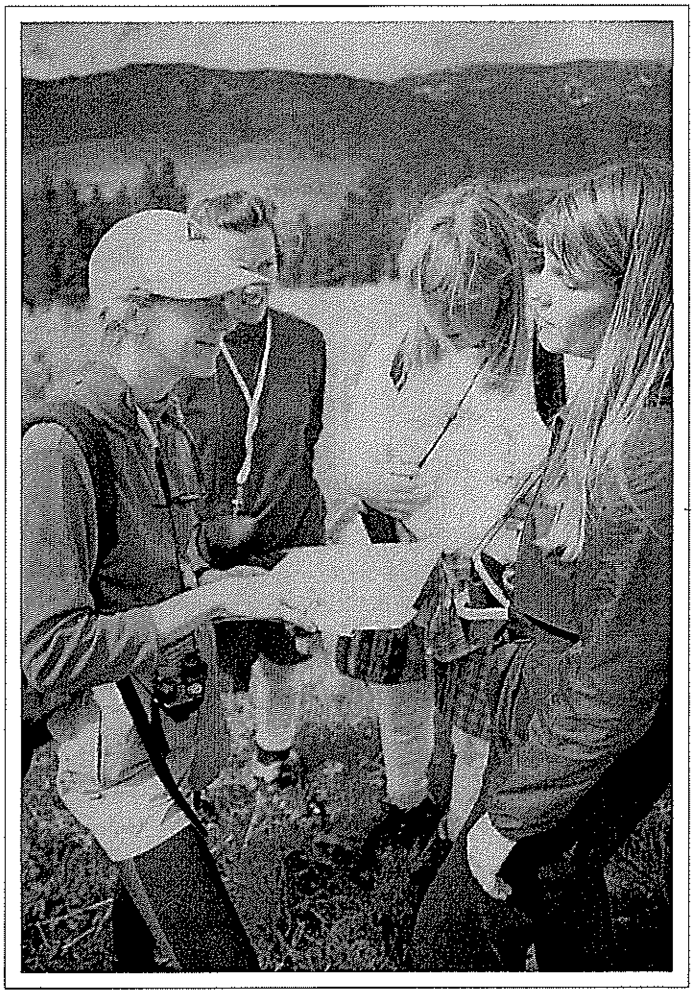
Yellowstone Science is published quarterly, and submissions are welcome from all investigators conducting formal research in the Yellowstone area. Editorial correspondence should be sent to the Editor, *Yellowstone Science*, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190.

Support for *Yellowstone Science* is provided by the Yellowstone Association for Natural Science, History & Education, a non-profit educational organization dedicated to serving the park and its visitors. For more information about the Yellowstone Association, including membership, write to P.O. Box 117, Yellowstone National Park, WY 82190.

Using Satellite Data to Support Fieldwork

Can species distributions be predicted?

by Diane Debinski



Above: The author, Camille King, Katie Horst, and Liesl Kelly discuss the results of their morning bird census at Twin Cabin Creek. Photos by James Pritchard.

Although species extinction has become a global concern during the last decade, our knowledge of species distribution patterns remains limited. If we don't know where a species has existed historically, we cannot determine if its range is contracting or expanding. This can make it difficult to identify a species as endangered until it is close to extinction. One way to address this problem is to try to predict which species may be at risk based on their habitat distributions.

A variety of on-the-ground techniques has been developed for monitoring species distribution patterns, but they are labor-intensive and costly. After conducting a three-year biodiversity inventory of birds and butterflies throughout the wide array of habitats in Glacier National Park, I became interested in developing methods to make field surveys more efficient and cost effective. Satellite data can be used to identify remotely sensed habitat types based on vegetation density, moisture content, and species composition. I decided to test the use of satellite data in predicting plant and animal species distribution patterns.

Although vertebrate biologists have long used knowledge of an animal's habitat to predict its presence, and more recently used satellite data to identify species-specific habitat sites, the use of remotely sensed habitat types to predict animal species distribution is still unrefined. The Environmental Protection Agency's biodiversity and habitat initiative is investigating the use of low-cost satellite data as an alternative to ground-based habitat assessment.

Our ability to distinguish different vegetation types using only satellite data may be limited. Spectral reflectance patterns are influenced by a combination of topography, moisture, elevation, and vegetation. Proponents of gap analysis (a technique used to compare locations of plant and animal habitats at a study site to those in existing preserves) use LANDSAT Thematic Mapper (TM) imagery to determine the boundaries of vegetation types. Then other data is incorporated (e.g., aerial and high-altitude photography and ground-based vegetation maps and field surveys) to label the vegetation types to series level. A major criticism of this approach has been that gap analysis does not involve enough ground-truthing of information. Even if a habitat appears suitable, we do not know how often a species actually occurs at the predicted site.

Research Objectives

My own goal was not to do away with local field sampling, but to use remotely sensed habitat types and geographic information systems (GIS) analysis to predict species distribution patterns so that fieldwork could be focused on specific sites within the study area. If remotely-sensed habitat types prove to be good predictors of species assemblages, this could provide a more cost-effective technique for monitoring biodiversity than ground-based field work alone. To test this hypothesis, I needed to:

- Determine the extent of the relationship between remotely sensed habitat types and plant and animal species distribution; and
- Test the predictability of species assemblages based on knowledge of this relationship.

The presence of a particular plant species at a specific site can be highly indicative of the particular microhabitat of that site. Because the plant species that provide dominant cover play a major role in determining spectral reflectance patterns, we needed to test the relationship between remotely sensed habitat types and the actual plant community. If plant species distribution could not be predicted using remotely sensed data, relationships between remotely sensed data and animal taxa would be highly unlikely. Thus, a plant survey is the critical link between remotely sensed data, habitat, and other species distribution patterns.

Research Design

My colleagues and I initiated this research to link habitat components (e.g., grasses, forbs, shrubs, and trees) with birds and butterflies. Our study area was the northwest corner of the Yellowstone ecosystem, from Porcupine Creek to Bacon Rind Creek (north/south), and from the crest of the Madison Range to the crest of the Gallatin Range (east/west). This area was chosen to develop our model because it includes a wide range of elevation and moisture gradients and the patchiness of post-fire successional habitats, and because bird and butterfly species lists, including more than 100 species of each, are available for the ecosystem.

Birds were used to test the hypothesis because they are conspicuous, ecologically diverse and use a wide variety of food and other resources, and are often more sensitive to environmental change than other vertebrates. Butterflies were chosen because they are well known taxonomically, easily identified in the field, and their diversity is correlated with underlying plant diversity. Birds and butterflies made a good combination because they are active at different times of the day. Birds were surveyed in the early morning, and butterflies from mid-morning through the afternoon.

Species and Habitat Characterization

The remotely sensed data were clustered into 50 spectrally distinct classes that were evaluated using U.S. Forest Service stand survey maps, aerial photography, and personal knowledge of the study area. A preliminary analysis resulted in a merging of the 50 classes to create five forest habitat types and six meadow habitat types. Mapwork and field surveys were then used to identify five spatially distinct examples of the three mixed conifer-forest and six meadow types, and 100 x 100 m plots were staked out at each of the 45 sites.

Habitat types were based on remote sensing cluster analysis, followed by ground-truthing with USFS stand-survey maps and aerial photos.

During the summers of 1993-1995, we inventoried each site for vegetation, butterflies, and birds.

- Trees were sampled by establishing a 100-m transect on one side of each plot and surveying every tree within 3 m on either side of the transect line for species and diameter at breast height.
- Meadows were sampled by estimating total cover for each plant class (forbs, grasses, and shrubs) within 25 one-m^2 plots, placed evenly along a 100-m transect. For comparison purposes, coverage estimates were also made for each class using a 100 x 100 m plot at each site.
- Birds were surveyed in 35 plots comprising three forest types (F1-F3) and five meadow types (M2-M6). We conducted aural and visual surveys using two groups of two observers moving systematically through the plots for 45 minutes. Sampling was repeated three times in

REMOTELY SENSED HABITAT TYPES

Forest	
F	Mixed conifer forest: lodgepole pine (*Pinus contorta*), Englemann spruce (*Picea englemanni*), and Douglas-fir (*Pseudotsuga menzezii*)
F3	High density
F2	Lower density
F1	Fairly sparse
DF	Douglas-fir
WB	Whitebark pine (*Pinus albicalus)*
Meadow	
M1	Hydric/lush meadow
M2-M4	Decreasing moisture gradient
M5	Moist sagebrush/cinquefoil meadow
M6	Xeric, mostly dry sagebrush shrubland

each plot during the summer of 1993.

• Butterflies were surveyed in 30 meadow sites (five of each of the M1-M6 types). Three people netted and released butterflies for 20 minutes in three randomly selected 50 x 50 m subplots. Sampling was repeated two or three times in each subplot during the summers of 1993 and 1995. Butterflies were not surveyed in forests due to their low density there and the difficulty of maneuvering with nets.

Comparing Satellite Data to Field Observations

There appeared to be significant relationships between remotely sensed data and the vegetation we found in our field observations, and these impressions were quantified. through statistical analysis, which showed several important relationships between satellite data and species distribution patterns of vegetation, birds, and butterflies.

Vegetation. Field surveys in 1993 validated the vegetation density, composition, and moisture gradients expected from the satellite data. For example, forest density decreased from F1 to F3 forests, and F3 forests tended to be located on steep, north-facing slopes. M1 and M2 meadows were characterized by sedges and grasses that prefer wet sites, and M3 meadows by willow thickets and flowering vegetation, while M4, M5, and M6 meadows were characterized by a progression of plants that tended towards the drier end of the moisture spectrum (e.g., sagebrush, fescue, brome, sedum, and aster). I will focus here, however, on the results of the animal data.

Birds. A total of 74 bird species and 42 butterfly species were observed during the surveys. Several species of birds exhibited a preference for one or more of the remotely-sensed habitat types. The frequency of seven bird species (mountain chickadee, brown creeper, American crow, orange-crowned warbler, hermit thrush, American robin, and song sparrow) was significantly different in the forest versus meadow habitat types. Except for the song sparrow, all of these species preferred the forest habitat types. This is what we would have predicted, for song sparrows are typically found in wet meadows, while the other birds are forest dwellers. When habitats were clumped into broad categories, preferences were as follows:

Butterfly surveys can be an aerobic sport. Here Camille King goes for the gusto in chasing down a vigorous swallowtail.

• The mountain chickadee, which is usually found in coniferous forests, preferred the forest habitat types to the meadow habitat types.

• The song sparrow and rufous-sided towhee preferred M1-M2, the wet willow meadows.

• The dark-eyed junco, which is usually found in forest or forest-edge habitats, preferred the forest habitat types to the meadow habitat types.

• The violet-green swallow, which is found in a variety of habitats including towns, preferred M5-M6 meadows.

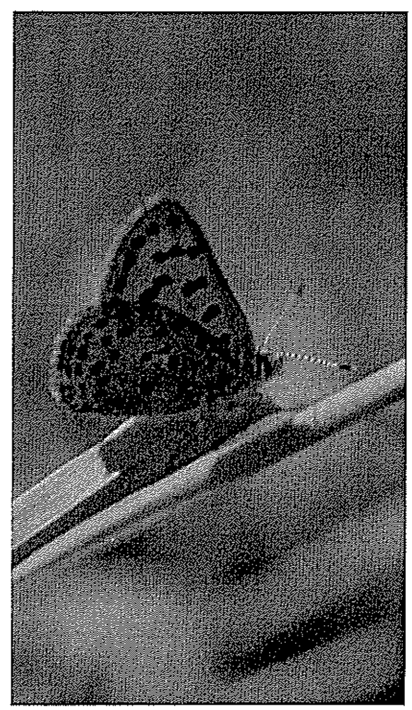
• The hairy woodpecker, which is often found in medium moisture meadows with aspen stands or dead standing timber, preferred medium to drier meadows (M3-M4).

• The American robin and red-breasted nuthatch preferred F3, the denser forest, while the ruby-crowned kinglet preferred F1, the more open forest.

Butterflies. Ten species were found in all meadow habitat types, while another ten species were each found in only one meadow type. Thirteen species showed significant preferences for one or more specific habitat types, including several species that were found only in extremely wet or dry meadows.

• Five species preferred M1-M3 habitat types (wet meadows). The Yellowstone Checkerspot *(Euphydryas gillettii)*, a species that typically prefers wet sedge meadows, was found only in M1 meadows (see cover photo). This butterfly lays its eggs only on a shrub called black twinberry (*Lonicera involucrata*), and only if the shrub is in a wet meadows. Checkerspot populations appear to be declining, and may become a species of concern in future years. Other moisture-loving species that showed significant preferences for M1 and M2 meadows included the greenish clover blue *(Plebejus saepiolus)* and four medium-size orange butterflies in the family Nymphalidae: the western meadow fritillary *(Boloria epithore)*, the silver meadow fritillary *(Boloria selene)*, the bog fritillary *(Boloria frigga)*, and the painted lady *(Vanessa cardui)*. The host plants of the fritillaries and the blue include willows, violets, legumes; the painted lady is more of a generalist.

• Four species preferred M4-M6 habitat types (dry meadows). Species such as the lupine blue (*Plebejus icariodes*), the ringlet (*Coenonympha inornata*), and the Mormon fritillary (*Speyeria mormonia*) showed preferences for M5 and M6 meadows. These species are typically found in



Some butterflies are more reclusive than others. Shown here is Lyceana mariposa, *the Mariposa Copper.*

Diane Debinski carefully examines a butterfly for identification prior to releasing it.

Katie Horst measures out the 100x 100m plot and stakes flags preparing for a census at Twin Cabin Creek.

sagebrush habitats and span a range of colors (tan, orange, and blue) and sizes. Their host plants include legumes, violets, and grasses.

• Four species preferred M3 or M4 habitat types (intermediate-moisture meadows), which were characterized by diverse flowering plants such as wild geranium, strawberry, prairie smoke and cinquefoil, but sometimes had a few sagebrush or willow as well. Butterflies found in these meadows included Sara's orange tip (*Anthocharis sara*), the orange sulfur (*Colias eurytheme*), the small wood nymph (*Cercyonis oetus*), and the dappled marble (*Euchloe ausonides*). All of these species are medium in body size and light in color. Their host plants include legumes, mustards, and grasses.

How Effective is the Use of Satellite Data?

We expected satellite data to be a relatively good predictor of vegetation, and this expectation was met by our data analysis. All of the plant species with minimum cover (at least 5 percent in at least one plot) showed a statistically significant difference among the remotely-sensed meadow habitat types. Forest habitat types were significantly different with respect to both density (F1 being lowest and F3 being highest) and species composition.

The next step was to determine whether satellite data could be correlated with distributions of selected animal taxa. Several species of birds and butterflies were associated with one or more remotely sensed habitat types. In some cases, our data showed that a species preferred a broad category of habitats (e.g., forest vs. meadow). In other cases, species distinguished among finer gradations of habitats (e.g., wet meadows vs. dry meadows). Several species, including the Yellowstone Checkerspot, showed a preference for one specific kind of meadow or forest. All of the species-habitat relationships we observed make sense given known species-habitat preferences.

Plants were much more highly correlated with remotely sensed habitat types than were animals. This can be explained by several factors: (1) the remote sensing image is reflecting the actual presence of these plants on the ground; (2) plant data are measured in terms of coverage while animal data are measured as presence or absence; and (3) plants are stationary on the landscape, whereas animals move through the landscape and may or may not be present when the data are collected.

Many factors besides vegetation type affect species presence and can cloud the observed relationship between species and vegetation. Even if a habitat appears suitable for it, a species may not be present because of historical factors (e.g., hunting) or competition with other species. In addition, species found in a wide range of habitat types will not demonstrate a statistical correlation with one specific habitat type. Many bird and butterfly species fit into this "generalist" category. Species that were found in only a few sites, on the other hand, do not provide enough data for rigorous statistical relationships. Thus, in order to predict where one might find a species using remote sensing and GIS methods, a species must be common enough and its habitat specific enough to exhibit a significant relationship with one or more remotely sensed habitat types. Our next step will be to use the models developed in Yellowstone to predict the species distribution patterns in Grand Teton National Park. The test of our predictive models will begin during the 1996 field season.

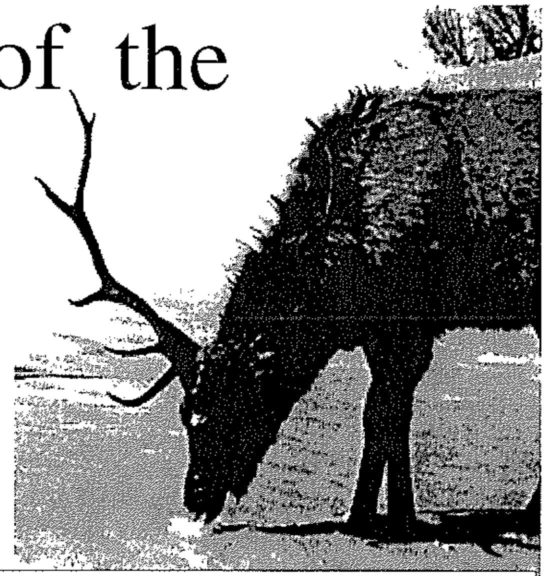
In summary, remote sensing will be helpful in locating possible sites for rare species with known habitat associations (e.g., a species restricted to dense forest or wet meadows) by identifying the portions of an ecosystem in which the species' habitat is likely to be found. This technique could also be valuable in setting up programs to monitor the effects of global climate change on the distribution of certain species. However, the limitations of this technique must be recognized; extremely rare species and species that are not habitat-specific will continue to require monitoring through more field-intensive methods.

Acknowledgements

This research was supported by grants from the University of Wyoming National Park Service Research Center and the University of Kansas' General Research Fund and Panorama Society. Evelyn Merrill, Alan Vandiver, and Ron Krager provided baseline data. I would like to thank Mark Jakubauskas for his help in creation of the maps, Kelly Kindscher and Alexandria Fraser for their botanical expertise, and Susan White for her assistance in data analysis. Camille King, Liesl Kelly, Katie Horst, Rebecca Hurst, Amy Trainer, Paul Rich, and Michelle Wieland assisted in the field work. The Gallatin National Forest and the Montana Department of Fish, Wildlife and Parks provided us with housing. Finally, I would like to thank Phil Humphrey and James Pritchard for their encouragement.

Diane Debinski is an assistant professor in the Department of Animal Ecology at Iowa State University. This article reflects her special interest in conservation biology and biodiversity assessment.

Migratory Behavior of the Jackson Elk Herd



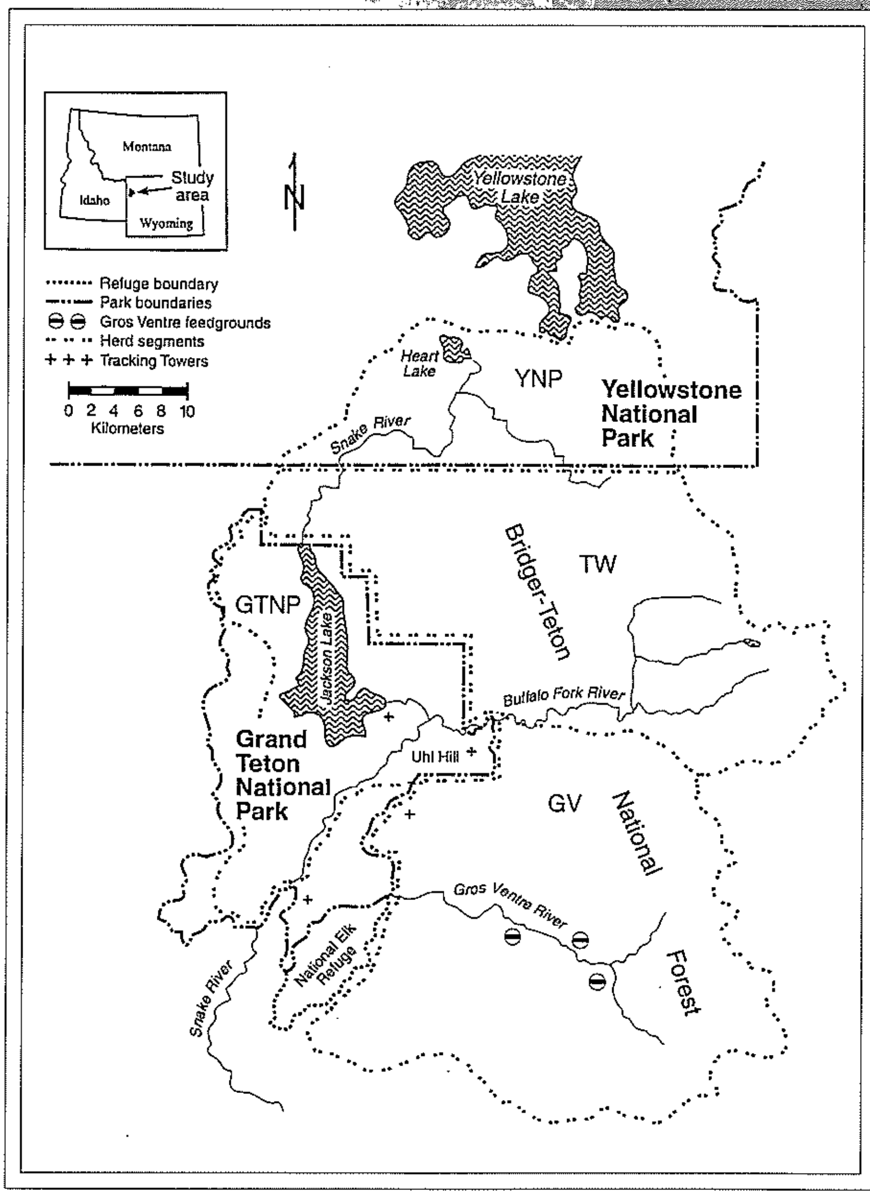
by Bruce Smith

Species inhabiting strongly seasonal environments often display a host of traits not possessed (or needed) by species living in environments lacking distinct seasons. These evolved traits enable animals to cope with periods of adverse conditions (drought, prolonged cold, deep snow) that influence individual fitness. These traits are both physiological (fat deposition, heavier winter pelage, reduced metabolic rates, water conservation, hibernation) and behavioral. One of the most widespread behavioral adaptations that animals have evolved is migratory behavior.

Migrations of large mammals between summer and winter ranges generally follow traditional routes that are learned, that is, passed on from mother to young. Even the casual observer will note that adult animals typically lead these movements. Bison and elk of Yellowstone National Park's northern range demonstrate a penchant to migrate down the Yellowstone River valley, perhaps as they did prehistorically. Unimpeded by humans, would bison and elk eventually relearn to winter across much of this valley and beyond each year?

Dr. Valerius Geist [*author of numerous papers and books on North American ungulates*] has pointed out that in mammal species that use patchily distributed habitats, the maintenance of traditions in a population is important. If the only bighorn sheep familiar with the location of desirable habitat patches are lost to the population, the traditional transmission of knowledge will be lost, and the use of the habitats discontinued. In populations that undertake long-distance migrations between summer and winter ranges, a similar loss of knowledge of migratory pathways could occur.

This is apparently the case in the Jackson elk herd, a portion of which is believed to have historically migrated out of Jackson



Summer ranges and winter feedgrounds of the Jackson elk herd.

Selection for Migratory Behavior

It seems logical that animals expend considerable energy to migrate to areas with more favorable environmental conditions. Therefore, migration has often been cited as an adaptive behavioral strategy that has evolved to avoid resource bottlenecks in temperate regions. The reasons that mule deer travel downslope to wintering areas with less snow and more available browse, or that waterfowl leave the frozen tundra for warmer climes each fall are apparent to us. It is less clear why they don't remain in those favorable climes yearlong. Thermoregulatory advantages, avoidance of insects, search for breeding areas, and other explanations of why migratory animals do not remain yearlong in the most mild of their seasonal ranges do not hold up. Some mule deer *do* remain on winter ranges all year, and Arctic nesting ducks and geese could find food and nesting habitat on their wintering grounds. Nor does aversion to crowding spur animals to migrate. Some of the most social species (colonial nesting birds and gregarious mammals like caribou) are migratory. The most parsimonious explanation for migration lies not in why individuals leave their most favorable seasonal range, but rather the evolutionary advantage of traveling to the least favorable one during relatively short periods of benign conditions.

Ultimately, migration improves long-term reproductive success by optimizing food available to parents before giving birth or laying eggs. Among mammals, the better the food resources during the pre-birth period, the more successful mothers are in providing milk and conceiving again. Milk production is highly correlated with growth of neonates, which positively influences winter survival in temperate latitudes.

Drs. John Fryxell and Tony Sinclair [*researchers of migratory mammals on the African savannah*] suggest that in addition to reproductive advantages, regulation of resident herbivores by predators may also favor selection of migratory behavior. In grassland ecosystems, migratory species of ungulates vastly outnumber sedentary species. In Africa's Serengeti, for example, nonmigratory herbivores often suffer higher rates of predation than migratory herbivores whose movements extend beyond the home ranges of lions and hyenas.

Hole to winter ranges in southwest Wyoming. The Jackson pronghorn antelope herd still undertakes this world class migration between winter ranges in southwest Wyoming and summer range in Jackson Hole. Although pronghorn all but disappeared from Jackson Hole between 1910 and the late 1950s, a handful of survivors apparently perpetuated this 300-mile migration.

The Value of Understanding Migratory Behavior

Aspects of migratory behavior are of particular interest to wildlife ecologists working in the Yellowstone ecosystem. Many of the bird and large mammal species of this highly seasonal environment are migratory. Understanding the location of migration routes and corridors is basic to conservation of individual populations. These corridors not only link geographically separate seasonal ranges, but often provide pathways for outbreeding and gene flow among populations. For example, in the upper Yellowstone River drainage, at least three distinct elk herds commingle during the fall rut and exchange genetic material.

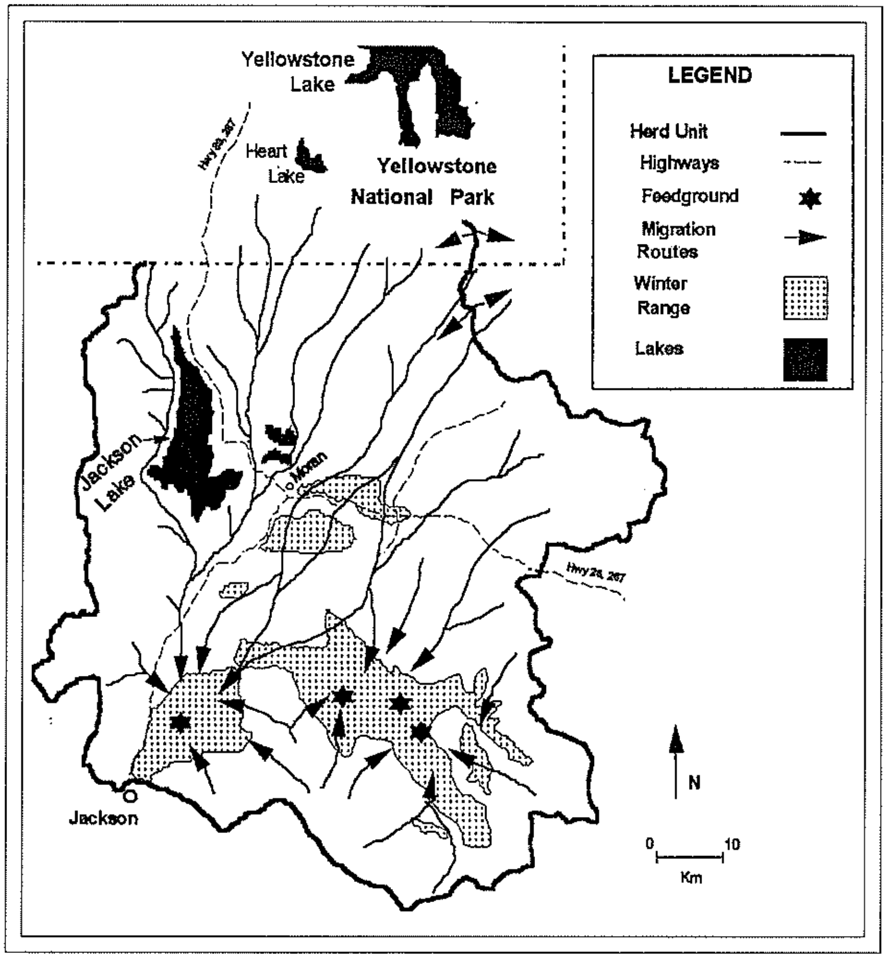
Wildlife managers who use hunting as a management tool must understand when and where populations migrate to design successful hunting seasons. The population that best exemplifies this is the Jackson elk herd, which is centrally located in the Yellowstone ecosystem. As elk stream southward each fall from their high-elevation summer ranges in southern Yellowstone National Park, the Bridger-Teton National Forest, and Grand Teton National Park, some 3,000 elk are harvested from a fall herd numbering 19,000-20,000. But all elk are not equally vulnerable to hunters. Therein lies the need for wildlife managers to understand when and where elk from various summer ranges make their annual pilgrimages to their winter ranges. Otherwise there could be heavy harvests of animals from some summer ranges and little harvest of others. This occurred in the Jackson elk herd 20-30 years ago.

Aside from the notoriety of its large size and 70-mile seasonal migrations, the Jackson elk may represent the largest challenge of any big game population in North America. So complex is the herd's management that private citizens are deputized as park rangers to carry out an elk reduction program in Grand Teton each fall. This is the only big game "hunt" conducted in a national park in the lower 48 states, although some other NPS units (i.e., national recreation areas) allow hunting. Moreover, elk are hunted on the northern half of the National Elk Refuge (NER), where 60 percent of the Jackson herd spends the winter. A key feature of the herd's ecology that necessitates these elk reductions is the winter feeding of much of the herd on the NER and on three additional feeding areas operated by the state of Wyoming. Feeding was initiated in 1911 to mitigate the conversion of former elk winter range in Jackson Hole to human uses.

Research on the Jackson Elk Herd

Two recent investigations have helped clarify migratory behavior of Jackson elk. In both studies my coworkers and I radiocollared elk and closely monitored their movements in relation to environmental conditions. In 1978, we initiated a study of the approximately 7,500 elk that winter on the NER. Our objectives and results, detailed in *Migrations and Management of the Jackson Elk Herd*, published by the National Biological Survey in 1994, are summarized briefly here.

We sought to gather information on the seasonal distributions of elk that wintered on the NER and to identify their calving locations, the timing and loca-



Migration routes of the Jackson elk herd.

tions of their migration routes, and the degree of fidelity elk had to these locations and patterns of behavior. We also intended to estimate annual harvest and survival rates of elk in each herd segment.

From 1978 to 1982, we captured, immobilized, and radio-collared 97 elk at random on the NER. From 1978 to 1984 we attempted to locate the 97 radio-collared elk (80 females and 17 males) three times each week during migration and approximately weekly at other times. We plotted radio locations on USGS topographic maps and determined membership of each radio-collared elk to one of the following herd segments: Grand Teton National Park (GTNP), Yellowstone National Park (YNP), Teton Wilderness (TW), or Gros Ventre (GV) drainage. Fidelity to seasonal ranges was measured as an elk's frequency of return to its previous year's winter and summer range. We delineated specific calving areas from relocations of radio-collared female elk.

In the second study, we captured 164 elk on Bridger-Teton National Forest (BTNF) during 1990-1992. Calves were fitted with expandable radio collars, which were replaced with adult collars during the animal's second or third winter.

Forty-eight percent of our adult radio-collared elk summered in GTNP, 28 percent in YNP, and the remainder summered on the BTNF (12 percent in the Teton Wilderness Area and 12 percent in the Gros Ventre drainage). Fidelity to winter range on the NER was 97 percent among adult collared elk that survived one or more years. Fidelity to summer ranges was 98 percent, and the fidelity of most animals went beyond returning to one of the four general summer ranges. For example, ten of the eleven adult radio-collared elk that summered in YNP returned to the same drainage or mountain complex each summer.

The migratory patterns we found were very similar among adult and juvenile elk. This is not surprising, given that elk generally migrate in mixed groups. The peak of spring migrations from the refuge occurred about three weeks after managers ended supplemental feeding in late March to mid-April, when new growth of grasses and forbs appeared over several thousand acres of the refuge. Growth began sooner when March temperatures were warmer, melting winter's snow and warming the soil. After a winter of eating dried grasses and a supplemental ration of alfalfa pellets for two to three months, the elk clearly preferred nutritious spring grasses. They grazed across the refuge and adjacent national forest slopes for two to three weeks and then began moving north, mostly at night, along traditional routes. The higher ridges were still snowbound in April and early May, so the Snake and Gros Ventre river valleys and their tributaries provided travel lanes.

Adult bulls arrived at distant summer ranges in southern YNP and the TW three to four weeks earlier than cows. This was largely a consequence of the cows interrupting spring migrations to give birth in favored habitats along the way. However, both bulls and cows arrived on summer ranges equally soon during spring 1981. What little snow fell the previous winter melted early that spring. Many of our radio-collared cows calved in 1981 on or very near summer ranges that in years of more typical snowpack would have provided poor foraging for females nearing birth and needing abundant nutritious forage for production of milk.

Annual fall migrations were likewise correlated with environmental conditions. During both studies, more than 85 percent of radio-collared elk wintered on refuge winter range (including the NER and adjacent national forest slopes, less than 2 miles to the east). Fall migrations commenced in October or November. Elk funneled southward along migration routes; topographic features such as Jackson Lake and steep escarpments concentrated elk in places. Ninety-four percent of radio-collared elk had arrived on the winter range by December 15. Duration of fall migrations varied with distances between the summer ranges and the refuge winter range. Elk from GTNP spent significantly less time migrating to win-

A four-day old elk calf radio-collared by the author.

Replacing the expandable radio collar on a yearling elk.

ter range than other Jackson elk. Some elk that summered in southern GTNP and the western Gros Ventre drainage migrated in one day or less. Elk that summered in the eastern Gros Ventre, Teton Wilderness, and YNP took from several days to eight weeks to reach the refuge after leaving their summer ranges.

Radio-collared elk from all summer ranges began migrating at about the same time. October precipitation was the foremost factor influencing when both males and females, juveniles and adults left high-elevation summer ranges in YNP and the Teton Wilderness. Annual arrival dates of migrating elk at the refuge winter range were inversely correlated with two variables: combined mean monthly July and August temperatures and snow depths at the south entrance of YNP on November 10. It is not surprising that greater snow accumulations prompted elk to migrate to the refuge sooner. But what effect could temperatures four to five months earlier have played?

The Need to Feed

In the Yellowstone ecosystem, below-normal precipitation accompanies high summer temperatures. Paltry precipitation during the growing season reduces vegetation production. Furthermore, when summer temperatures are high and precipitation low, plants become stressed and cease growing sooner. This affects not only the total biomass produced, but also the length of time that elk enjoy the more nutritious and digestible green vegetation. Elk must consume copious amounts of high-quality forage during summer to lay on fat, which is later burned to alleviate nutritional deficits during winter. Nearly 25 percent of the NER is either irrigated by refuge staff or sub-irrigated (a high water table provides moisture to the plants' root zone). This, combined with the fact that the refuge is largely ungrazed during summer, means that abundant forage, some of it still green, remains when elk arrive each fall.

There is additional evidence of the importance of forage. Elk spend summer and fall primarily in GTNP west of the Snake River where hunting is not permitted. Elk leave the west-side sanctuary each fall and migrate to the refuge winter range when little snow covers the ground. When they cross the Snake River, elk are hunted in both the park and the north half of the refuge. My studies of forage production and forage use in GTNP suggest that elk leave the park because they are forage-limited, in quality and/or quantity. They migrate to the refuge earlier in years of lower forage production and when less forage remains in areas where large herds congregate west of the Snake River. They chance the perils east of the river to garner the forage bonanza at migration's end.

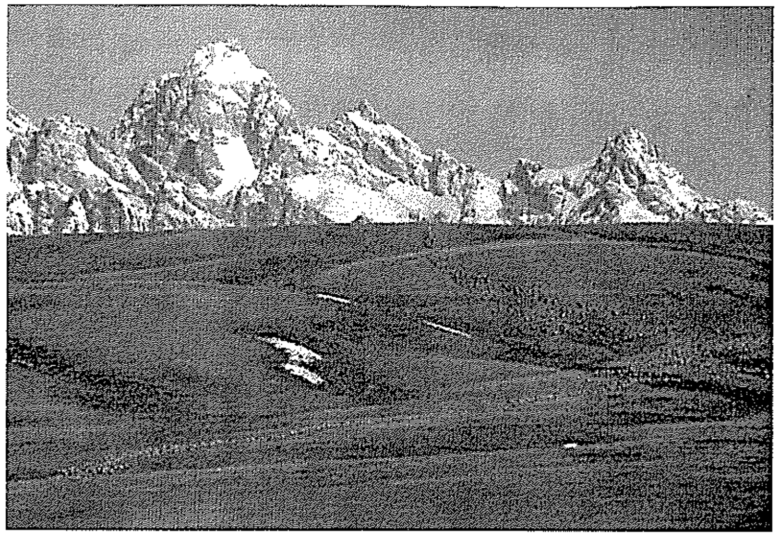
From an elk's viewpoint this strategy has been successful. Winter mortality has averaged just 1.4 percent of the elk that wintered on the refuge in recent years, and early migrations have not resulted in significant proportions of the herd being culled annually by hunters in the park and refuge. The number of elk wintering on the NER has doubled since 1984. The elk often migrate in large herds and many migrate under cover of darkness. For example, 2,700 elk streamed into the refuge the night of November 12, 1988. And when forage supplies become depleted or frozen beneath a blanket of snow on the refuge, the elk are fed. These migration strategies can therefore be considered adaptive.

Managing Migratory Elk

Our experience leads us to conclude that refuge and park hunts are vital in controlling elk numbers in GTNP, given the low rate of winter mortality of the Jackson herd. All but a few elk that summer in Grand Teton migrate to the refuge winter range. Thus the park and refuge are the only lands on which those elk can be harvested. Their shorter migrations result in GTNP elk arriving an average 6-29 days earlier at the refuge each fall than elk from the other summer ranges, which migrate and are hunted across large expanses of the BTNF. Numbers of elk that summer in GTNP have quadrupled over the past 40 years and are now approaching 5,000. The reasons for the increase in the elk population include the removal of livestock and the cessation of hunting from park lands west of the Snake River that were privately owned, hunted, and supported few elk before 1950.

In large measure it is the migratory behavior of the elk and the number of permitted hunters that dictate the harvest. These limits are most evident within the confines of GTNP and the NER where the harvesting of elk is essentially a herd reduction program. Wildlife managers schedule hunting seasons in the southeastern part of GTNP and in the NER to coincide with the start of the earliest-recorded migrations. The U.S. Fish and Wildlife Service maintains about 60 radio collars on elk to monitor the migration's progress. The refuge hunt ends when 80 percent of the radio-collared elk that summered in GTNP arrive at the refuge. This percentage best coincides with the maximum arrival of GTNP elk and the least number of elk arriving from more distant summer ranges. Closing the refuge season at that time permits migrating elk to disperse and forage across much of the refuge and onto the adjacent national forest winter range, where hunting closes before or in concert with the refuge season. The refuge has weekly drawings for permits, and its hunting season can be terminated on a week's notice to the public.

The GTNP season continues longer some years to encourage hunters to harvest elk from southern YNP that migrate later through Grand Teton to the refuge winter range. In years when the migration has begun late, such as in 1993, hunting seasons in the Jackson area have closed before many elk have left Yellowstone. Ending dates of hunting seasons, which must be decided by the Wyoming Game and Fish Department the previous spring (with no hint of how the fall migration will shape up), are difficult to change on short notice. Heavy October snows can render even the best of forage crops unavailable and speed the progress of migrations. Consequently, data from past fall migrations still provide the sideboards for next year's hunting season dates. However, because one of the goals of science is to predict future events, the potential to predict elk migrations from growing-season conditions has been an exciting discovery. Our research also helps us better understand the role that density-independent factors (those independent of the number of elk) play in the migratory behavior of elk.



Exodus of 2,000 elk from the National Elk Refuge in spring.

Harvesting Yellowstone's northern range herd is likewise dependent on migration of elk from the park. Heavy fall snows and the size of the herd both affect the timing of migrations, the number of migrants, and the potential harvest. Similar patterns are seen in other parks that provide safe havens for deer and elk populations. These animals know the park boundaries and avoid leaving them until the threat of starvation overcomes their fear of human predation. In many of these parks, heavy browsing has seriously altered the composition and structure of woody plant communities, impacting many other wildlife species and the diversity of park landscapes. In some cases, human activity has curtailed migrations out of the parks and increased densities of herbivores within park boundaries.

Conserving the Spectacle of Migration

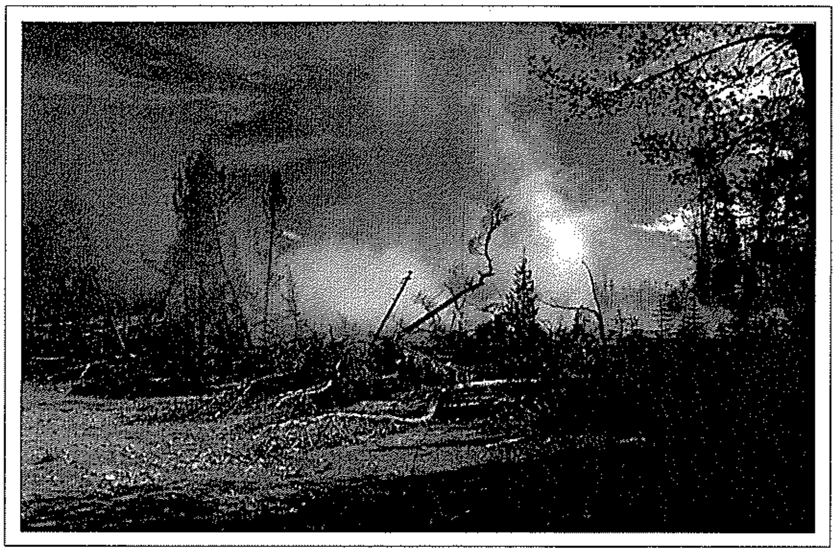
The establishment of Yellowstone National Park in 1872 and the National Elk Refuge in 1912 has been critical in the protection of elk from market and antler hunting and usurpation of critical habitat for human uses. The restoration of pre-1950 distributions and migrations of elk east of Grand Teton National Park remains an important objective of state and federal agencies because of the recreational, aesthetic, economic, and ecological benefits of conserving elk throughout all summer ranges in the national forests and the national parks.

Management of migratory herds of elk and other animals will continue to challenge wildlife and land managers as these herds become squeezed into smaller and smaller ranges by the encroachment of human enterprise. Former wildlands become fragmented, populations become isolated, their winter ranges compressed, and migration corridors obstructed.

The large predators on these migratory herds are often the first to decline in numbers as wildlands are "tamed" by humans. Bears, lions, wolves, coyotes, and other carnivores serve to facilitate a balance among the herbivore species and their densities in natural systems. Our large remaining ecosystems, such as the greater Yellowstone area, must be conserved to provide a remnant of what was common across western North America just 150 years ago. Only in these large blocks of habitat can the spectacle of migrating elk, other large migratory herbivores, and their complement of predators continue to flourish.

Dr. Bruce Smith is a wildlife biologist with the U.S. Fish & Wildlife Service, stationed at the National Elk Refuge in Jackson Hole, Wyoming.

The Ongoing Thermal Evolution at Astringent Creek



Extensive stand of trees killed by heat flow that preceded the emergence of the violent 1995 mud volcano.

by Roderick Hutchinson

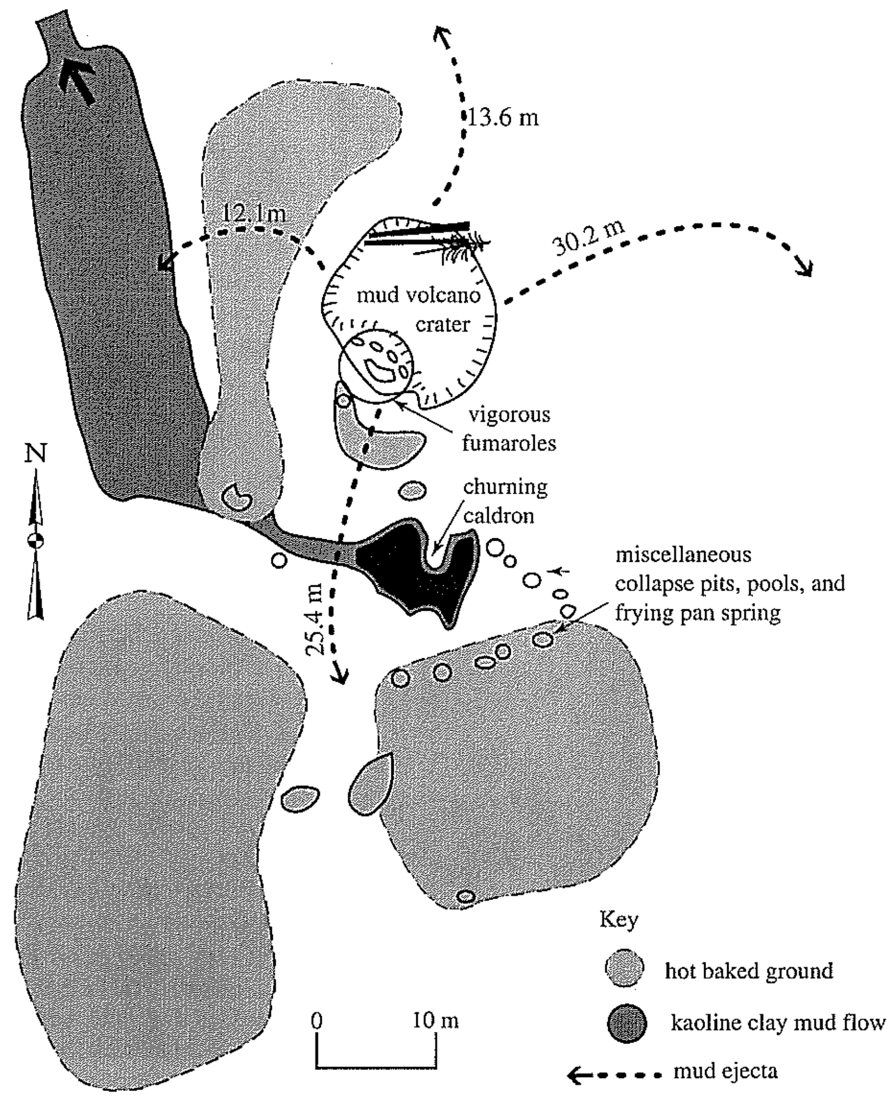
On the southeast flank of the Sour Creek Resurgent Dome near Pelican Valley, in the 600,000-year-old Yellowstone caldera, is an extensive acid-sulfate hydrothermal system. Surface expression in a newly active 3km^2 thermal area west of Astringent Creek, includes discontinuous high-temperature-altered ground, turbid springs, pools, seeps, fumaroles, and mud pots. There is also a large, gassy, sulfur-rich acid lake, and numerous sublimated sulfur-mound deposits interspersed among low-temperature, forest-covered ground.

1985: A Thermal Cycle Begins

An evolutionary cycle was first observed beginning in 1985 at the upper eastern margin of the Mushpots thermal area. This cycle has been characterized by areas of new hot ground, dying mature forests, and the vigorous breakout of a dry, super-heated fumarole with progressively hotter temperatures over time, followed by the sudden emergence of a large and violent mud volcano. The Mushpots thermal area is located near the western flank of Pelican Cone, about 4.5 km (2.8 m) east of the new Astringent Creek area, which has similar chemistry and is part of the same hydrothermal system.

Sometime during early 1990, a significant rise in temperature there began killing a grove of pine trees. Within a year, a new super-heated fumarole emerged among the roots and centuries-old fallen trees, quickly blanketing them with a layer of hydrothermally altered coarse sand from a directed blast to the north. The dynamic activity of the fumarole and surrounding hot ground was closely monitored twice a year starting in 1991. More frequent visits were not possible due to the area's remote location and restricted access through the Pelican Valley Bear Management Area. The feature's temperature and the volume of dry steam from the deep shaft-like vent steadily increased over the next three years to a maximum of 104.3°C (220°F), measured on October 8, 1994. The local boiling point at the feature's 2,585 m elevation (8,481 ft) is about 93°C (199°F).

Inspections after 1991 of the acid-sulfate thermal area west of Astringent Creek showed ample evidence that a series of seven large craters had apparently followed the same pattern as the Mushpots. They were progressively younger in a



Sketch map of new emerging features and unstable hot baked ground in thermal area west of Astringent Creek, June 7, 1995.

> **A Glossary of Thermal Features at Astringent Creek**
>
> • **Cauldron.** A hot spring pool with churning or agitated water.
> • **Collapse pits.** Small depressions in thermal ground produced by removal of material at depth by hydrothermal processes.
> • **Frying pan springs**. Shallow, vigorously active bubbling or boiling hot springs, usually in sand or gravel, with agitation similar to the sizzling of hot grease in a frying pan.
> • **Fumarole.** A steaming and/or gaseous vent lacking water.
> • **Mudflow.** A mass of mingled earth particles and water that flows like lava from a volcano.
> • **Mud pot.** A hot spring with fine clay mud of any viscosity (soupy to stiff mortar), usually having no discharge.
> • **Mud volcano.** A large, violently active mud pot with material ejected out to build up a cone or mound.

southwesterly direction, ending at the site of the current new hot ground and fumarole. A prediction that the newest super-heated fumarole would soon evolve into a large mud volcano was published in an article I wrote for *Eos Transactions* in December 1993.

1995: A Mud Volcano Erupts

As part of routine monitoring, the site was inspected on June 7 and September 12, 1995, and again on April 22, 1996. In place of the former 104.3°C (219.7°F) f umarole was a large, vigorous mud pot with an extensive area of ejecta produced while it was active as a mud volcano. Also new were two smaller roaring fumaroles at or slightly above boiling temperature, three moderate-sized churning cauldrons, and numerous smaller muddy pools, collapse pits, and frying pan springs. Under the fallen trees were extensive areas of unstable quicksand-like saturated ground made up of scalding mud. Some regions were heavily encrusted with sulfate minerals or sulfur crystals; others were deceptively covered by baked pine needle forest duff.

Extending northwest from the largest parasitic churning caldron was a spectacular white kaoline-clay mud flow. It rapidly spread out to an average width of 13.8 m (45.3 ft) in the first 55 m (180 ft) of its length in the dead forest grove before terminating on the treeless, acid-thermal basin floor 114 m (374 ft) from its source.

Judging by the freshness of the ejected mud and incorporated, semi-coarse sandy material, the rapid collapse and transformation of the super-heated fumarole into the powerful mud volcano is estimated to have occurred sometime between mid-April and mid-May of 1995. The volcano crater, which was active as a vigorous, moderately thick mud pot, was 13.5 m (44.3 ft) long , 11.3 m (37.1 ft) wide, and 3.9 (12.8 ft) to 4.9 m (16 ft) deep. Conservatively estimated, the crater volume was 315 cubic m (11,000 cubic ft).

Large bombs of mud probably attained heights of 20 to 30 m (65 to 100 ft) above the crater rim, based on the maximum distance that mud had been ejected—more than 30 m (98 ft) from the eastern rim. When the site was last inspected, mud was still being thrown up between 0.5 and 1.5 m (1.5 to 5 ft) from dozens of points all over the crater floor. Total area

NPS photos Rick Hutchinson

A large white thermal clay mudflow issued from a parasitic caldron-like vent below the 1995 mud volcano in an area of unstable hot ground (steam in background). The mudflow has buried sapling trees.

There is a chain of seven craters that pre-date the 1995 mud volcano (steam in background); the youngest is in the foreground.

View into new mud volcano crater. Its buried rim is bridged by mud-encased tree trunks killed by the thermal activity.

Closeup view of source vent of thermal mudflow.

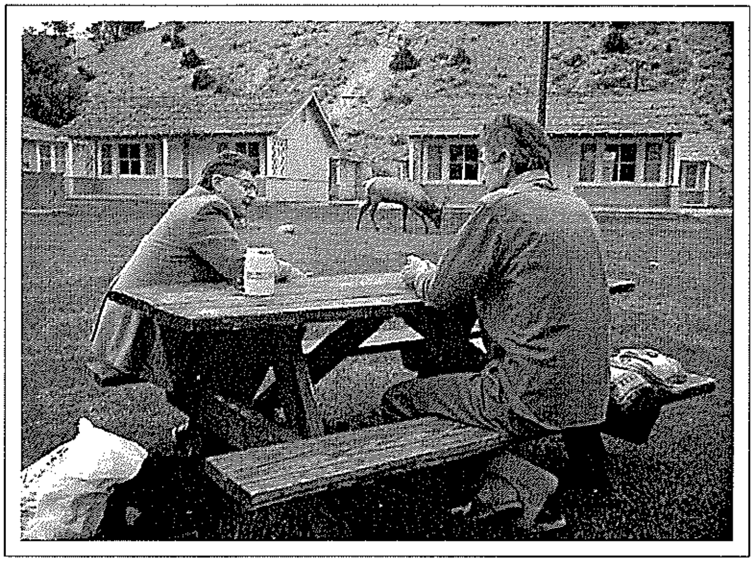
covered by the ejecta and crater was approximately 2,100 m^2 (22,000 ft^2).

In the southwestern quarter of the crater, a large, slightly elevated projection was visible with an arcuate (curving) line of dry white, probably super-heated fumarole vents. A pair of large logs bridged a portion of the northern crater rim that appeared on the verge of collapse.

The largest cauldron had numerous points of ebullition (bubbling activity) in its irregularly shaped pool, with maximum dimensions of 10.8 x 7.9 m (35.4 x 25.9 ft) and a water level 0.7 to 1.4 m (2.3 to 4.6 ft) below the sloping forest floor. The cauldron's churning water was near-boiling, opaque, and light tan in color, and partially covered with a medium-brown, organic-rich foam derived from cooked plant material. Both of the cauldrons are interpreted as being parasitic to the mud volcano crater, because they appear to have evolved shortly after the initial fumarole collapse, then subsequently drained away much of the fluids. Such a relationship seems to have rapidly lowered the crater floor and prevented accumulation of a thick ejecta cone on the crater rim.

The mud volcano crater, parasitic features and vents, plus most of the associated hot ground, remain extremely dangerous and unstable. Additional changes in the manner of new or enlarged springs and perhaps even another mud-volcano crater are anticipated. With respect to geologic hazards, the acid-sulfate thermal area is being monitored regularly. Photographs were taken to document the activity in June 1995 and on subsequent visits. Like the recent intense swarms of seismic activity noted by Robert Smith [*professor of geophysics at the University of Utah*] at the Western Wyoming Earthquake Awareness Symposium in Jackson Hole on June 15, 1995, hydrothermal outbreaks at the Mushpots, Norris Geyser Basin, and west of Astringent Creek are wake-up calls warning of future life-threatening geologic unrest in the Yellowstone region.

Roderick Hutchinson is Yellowstone National Park's research geologist; he has been studying and exploring Yellowstone's thermal areas for more than 25 years.

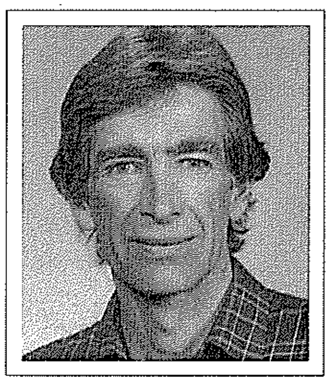


Saving North America's Grizzly Bear Ecosystems

And some new ideas on bear attacks

Steve Herrero is a professor in the environmental science program of the faculty of environmental design at the University of Calgary, Alberta, and a leading spokesman and advocate for ecosystem management, especially in the wilderness parks of western Canada, where he has conducted many years of research on carnivores. His book Bear Attacks: Their Causes and Avoidance, *has become a widely-read reference for hikers, biologists, and managers since it was published in 1985. In a recent survey of bear-management and ecology professionals who were asked to name the most important contributions to the bear literature since the 1960s,* Bear Attacks *was the runaway favorite, named more often than any other popular or scientific work.*

In September 1995 Steve was the keynote speaker at the Superintendent's International Luncheon of the Third Biennial Scientific Conference on the Greater Yellowstone Ecosystem at Mammoth Hot Springs. John Varley and Paul Schullery conducted this interview during a break in the conference events, at a picnic table in the cabin area behind the Mammoth Hot Springs Hotel Recreation Center. The conversation was interrupted several times by a bull elk, bugling as he passed the table. His bugles have been deleted from the transcript.



In Case of Bear Attacks

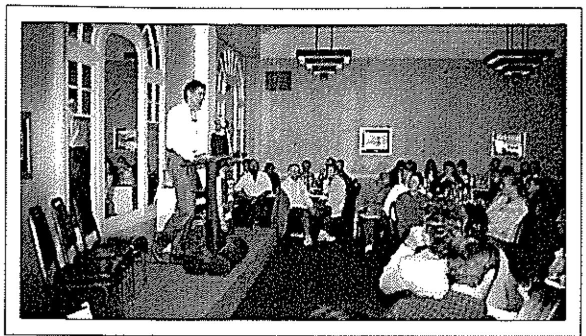
YS: Steve, before we get into our big-picture questions, let's talk about one of your well-known specialties, the study of bear attacks. You've been re-evaluating some traditional approaches to dealing with bear attacks, and I'm sure many *Yellowstone Science* readers would like to hear about it.

In your book *Bear Attacks*, you gave advice on the best way to play dead when near a grizzly bear, suggesting that rolling up in a "fetal position" was probably the best defense. More recently, based on additional information, you've been reconsidering that. You now recommend that rather than roll up in a ball, you should stretch out face-down, cover the back of your head and neck with your fingers interlaced, and spread your legs apart, digging your toes into the ground so that it's difficult for the bear to roll you over.

Photo top left: John Varley, Director of the Yellowstone Center for Resources, and Steve Herrero during the course of this interview.

SH: That's right. And it's based on the fact that grizzly bears often seem to flip people over, which allows the bear to get at that most vulnerable part of the human anatomy, the face. And the face is so delicate, with so many nerves and points where extensive damage can occur, that you really want to be able to protect it. One of the ways of doing that is to play dead.

As you said, the two strategies for playing dead that we've examined are curling up in a ball or lying face down on the ground. Curling up in a ball is the well-known approach that is most often recommended, but I now think that lying face down may be better. I don't think that there is a one hundred percent assurance of this new approach working best all the time, but it seems probable that you are better able to protect your face by lying flat, with your face on the ground, hands behind your neck, and legs spread out. In that position, if the bear tries to flip you over, you're more stable, because



The Superintendent's International Luncheon.

you have a lot of leverage in your legs that help hold you on the ground in that position. And if you do lose your stability and the bear succeeds in rolling you over, you can just continue to roll *completely* over and end up back with your face down again. I've looked at a couple of incidents in which people have done that and it's worked. So it's hardly something that has been studied scientifically, but it is something that I've played with. In other words, a colleague and I have played bear and person being attacked. Personally, I would certainly do it; I've rehearsed enough that I'm comfortable with it.

YS: What is the latest thinking on what to do if you're charged by a grizzly bear? At that point, it's pretty late to play dead, isn't it?

SH: Playing dead for a charging grizzly bear might even be the *wrong* thing to do. If I'm charged, I am going to stay on my feet until the bear actually contacts me.

Playing dead for a charging grizzly bear might even be the wrong thing to do. If I'm charged, I am going to stay on my feet until the bear actually contacts me.

YS: But doesn't that risk sending the bear the wrong signal, by suggesting that you're going to accept its challenge and fight back?

SH: I've looked at far too many situations where the bear charged, but stopped only feet away. A lot of charges are only bluffs, but if you run or act submissive at that last minute, you may actually trigger an attack. So I am going to stand there until the bear hits me, and then the moment it hits me, I'm going to play dead.

YS: Some of the old-time hunting writers used to maintain that virtually all charges by brown and grizzly bears were false charges anyway, and that it was usually best just to stand there and wait for the bear to stop.

SH: The knowledge we have about this may also come from watching the bears interact with each other. If one bear charges another one, and the second turns to run, it's almost certain to get clobbered. But if it stands its ground, the two bears may go through a lot of roaring and moving around, but most of the time neither of them will get clobbered.

There are no guarantees in any of this, but running or showing submission seem to be asking for punishment in those last seconds of the charge. That is why, based on my analysis of the hundreds of incidents we have in our bear-attack data base now, I'm not going to play dead until I've been knocked down.

Managing Habituated Bears

YS: As wildlife watching becomes more popular, and as bear-viewing areas become well known, both bears and people learn more about each other. What are we learning about bear-human tolerances, and how can we apply it more broadly?

SH: That gets us into this whole business of habituation and how safe habituated grizzly bears can be provided you're not camped next to them. Habituated bears are bears that have developed a tolerance for having people near them.

YS: These are what used to be called "tame" bears in Yellowstone, because they let people get very close to them.

SH: Right. The trouble was they weren't tame at all. But habituation can be managed in ways that make it possible for bears and people to be close together, provided that the people understand that they must abide by the rules of the game, and make their actions very predictable so the bears are never surprised.

I spent a large portion of the last two summers in Alaska, and I've now been to almost all the major bear-viewing sites, so I have a much more personal, intimate understanding of just what can be done through habituation.

YS: Do you mean in terms of using habituation to improve bear watching opportunities?

SH: Yes. Habituation allows a tremendous quality of human experience and at the same time it reduces stress to the bears. You can have bears only two meters away from you, even if they're females with cubs, and still be reasonably safe. But they have to have gotten used to that closeness over a significant period of time, and all human actions have to be totally predictable.

YS: That's all there is to it? Just being predictable?

SH: The other essential ingredient is that there must not be anything that those bears can exploit people for, such as packed lunches. Once it's gone that far, and the bears have learned that they can't exploit people for food, then you can even sit there and eat your tuna fish sandwich with the bears two meters away, and they won't try to take it from you.

YS: We've wondered for years about ways in which we can apply the Alaska experience to Yellowstone, to see if we can find ways to improve bear viewing here. It's already outstanding in some seasons, as you know, but it's necessarily a long-distance business, with bears watched through spotting scopes. We don't even know that we want it any different, but the close-up bear watching that goes on in Alaska intrigues us.

However, part of the folklore, even among bear managers, is that Alaska is different from Yellowstone or Glacier, and that we can't put people and bears that close together down here because of those differences. The difference we hear the most about is salmon; nowhere here do we have the extraordinary salmon runs that, in effect, put those Alaskan bears in such an easy mood. They are enjoying an overload of food when they're being watched up there in Alaska, and not only does that concentrate them in a small area, it makes them less likely to get aggressive about a tuna fish sandwich. At least that's the way the thinking goes. How does all that sound to you?

SH: I think the differences are real. With these richer, concentrated food sources at the salmon streams, the bears have to share space with each other. That means that they have to have a smaller personal distance—what you might call their individual space. They're used to being shoulder to shoulder with each other, and that sets the stage for habituating to people at very close range.
YS: But couldn't it be argued that for 60 years here in Yellowstone, when the bears gathered at the garbage dumps, we were "training" them to have that same small individual space? By the 1960s, there were dozens of bears using a single dump, and they were packed in there close together.
SH: I'm sure you could argue that. But remember the other part that is necessary to make the whole thing work. It isn't enough just to get the bears used to being close together. Human behavior has to be predictable, so that the humans are moving and acting consistently, and not surprising grizzly bears. Besides that, there has to be nothing that the grizzly bears can get from people. In other words, they can't push people around and get food from them.

That's where Yellowstone is so different, because it's such an open system, and a very diffuse system. In the Alaskan bear-viewing areas, managers can control what those bears can get from people. Managers absolutely control food storage in the camp near the viewing area, and absolutely control where and how people move. There aren't any other potential sources of human food for a considerable distance. None of that is true in Yellowstone.

Let me add another corollary of the Alaska work. This is something that's come out very clearly. The managers at McNeil River Falls will allow ten visitors at a time at the bear-viewing platform, and even at that level—even after twenty years of developing habituation and getting these bears accustomed to very consistent human behavior—some of the wariest bears still stay away from the site until the people are gone. They just feed nocturnally. What seems to happen is that you behaviorally structure the population into wary bears on the one hand and bears that aren't wary of people on the other.

Yellowstone's complex road system adds to the potential for bear-human conflict.

When you design a program around people watching habituated bears, you have to take all this into account, and look at what the effects are on bears with different behaviors.
YS: One of the things that has been revealed by the study of grizzly bear habitat use in Yellowstone is that the bears tend to abandon most roadside areas once the car traffic begins. They may use those areas all night long, but only a few habituated bears will stay once there is traffic.
SH: You start off with the proposition that grizzly bears left to their own devices are primarily a diurnal species, who have good reasons to be active during daylight hours. Bears use their vision a lot, whether fishing for salmon or chasing elk; the less light there is, the less effective they will be. So when bears shift their use of the habitat to a more nocturnal pattern, you can be sure that we're having a major influence on their behavior.
YS: The Frenches, (of the Yellowstone Grizzly Foundation), who have observed hundreds of predation episodes in Yellowstone, have emphasized the importance of the bear maintaining what has been referred to as a "visual lock" on the elk they are chasing. If they lose that, they lose the elk.
SH: And we've observed the same thing in Banff National Park in Alberta. Our grizzly bears do their elk hunting in the backcountry in the daytime. So the human influence on bear behavior must always be part of the equation in evaluating different interpretive and management options.

But at the same time, you have to be sympathetic to the viewing needs of people, because those viewing opportunities have such tremendous value. Perhaps a combination of a number of management approaches in different areas in a park might work, as would thinking about ways to screen the people and vehicles to reduce the visual impact on the bears.
YS: Another option, though it would be a tough one for Yellowstone with its complex road system, is to control access to certain roads, either by limiting the number and location of vehicles at certain seasons or certain times of the day, or by putting people in buses.
SH: The Denali National Park situation shows that you can get a significant number of bears and other species habituated to regular bus traffic. Once again, it's not to say that the most wary individual animals aren't affected by the bus traffic on the road.

Seeing the bear isn't necessarily the most important experience that people can have. I think that the opportunity should somehow be making a vital connection with the bear's world.

The apparent success of an approach like that, where the animals are very visible, leads to misunderstandings, though. The first thing people always say is, "Well, we see bears right along the road," or, "Well, the bears come right into town, so obviously our activities don't bother them." That simplistic outlook drives me crazy because it ignores so much that might be happening to the rest of the population while a few bears are willing to hang around near the roads.
YS: This often comes down to determining just what visitor opportunity is the best one to be provided. The presumption has always been that the best thing, in fact the requisite experience, is to see the bear, and get the obligatory picture of it.
SH: I don't even know if seeing the bear needs to be the opportunity. Seeing the bear isn't necessarily the most important experience that people can have in that situation. I think that the opportunity should somehow be making a vital connection with the bear's world. That connection may come from the chance to spend time in an area where you can see the elk calves out there running around, and just spend time talking about it all, or seeing the diggings a bear has made, or bear scat. These are ways to make the essential connections without having the great show in the 500 m lens that so many people insist upon. Let's be realistic; if we have to rely on the great show in the camera, we're never going to have more than a few people get into the bear's world and appreciate what wonder is to be had there. But if we try to broaden the interpretive links, for example through the various traces that bears leave in their environment, then people can get a vital, powerful experience just by sharing the land of the bear for a moment. Because they saw bear sign, they know that the bear is there and that they've made a contact with its physical presence that in a way is even more powerful than seeing it a mile away through a spotting scope. With that kind of experience in mind, we can reach a tremendous number of people.
YS: Perhaps it would be possible to have a 50-yard stretch of road that was made of fine sand or some other soft surface that you could rake smooth every evening. Then in the morning, people could explore it for tracks and other sign.

Saving Grizzly Bear Habitat

But let's move along to other larger questions about bears and conservation. Many of us here are convinced that at least the short-term prognosis for the Yellowstone grizzly is pretty bright. The evidence suggests that the population is doing pretty well.
SH: Yes.
YS: But we don't know anybody, at least not anybody with a reasonably sound perspective on the future, who thinks that the long-term prospects for the grizzly bear in greater Yellowstone are anything but grim. The grizzly bear is resilient enough to handle ski areas, or hard rock mining, but nobody with even half a brain believes that the bear is resilient enough to handle the entire array of civilization encroachment that we're seeing here.

In years like this one (1995), when specific food sources fail or are poor, the bears know how to adjust and find other foods. But we are more and more in the way of that process, so we've got bears in dog food, in horse oats, in bird feeders, and in a lot of other places that are hard on bears. Maybe the big question is, are we kidding ourselves that we can keep the bear for the long term with all these conflicts?
SH: Not necessarily. Never second-guess what the future is going to be like in terms of the possible changes in human behavior. Who would have predicted that smoking behavior would be regarded as it is today, twenty years ago? All we need to do is generate a population that believes that our ecological disruption and dismemberment of natural systems is as deleterious to our health as smoking is, and you'll see a whole lot of behavioral changes in people. In the meantime, by learning what the critical habitat features are, and by studying the movement corridors between them and the way that bears might use them, we have the potential for managing the grizzly bear ecosystem.

As long as there is a future, there is the potential for us to see major changes in human behavior and human expectations in the broader region. And once Americans, Canadians, and people anywhere decide to care, there is tremendous potential for giving back to wildlife and natural systems those areas critical for them—areas that we've learned about through study. So no, I'm not entirely pessimistic about the future. If I were, I'd probably be doing something else.
YS: There is a population of brown bears, the same species as our grizzly bears, in Italy that you're familiar with; it's a small isolated population of bears that's been through world wars and is surrounded by thousands of armed people and yet it still keeps going. Is that the sort of island ecosystem we're headed for in greater Yellowstone?
SH: Let's hope we're not going that way, because there the bear has been so harassed by human beings over centuries that it hardly even acts like a brown bear anymore; it's as if it is evolving into a black bear. It is small, extremely shy, and nocturnal, and it does everything more like a black bear than a brown bear.

But at the same time, even in that situation there is potential for improvement. The habitat under protection has more than doubled since 1971, and they are managing beyond a park boundary into a greater ecosystem. The only hope for a real future is a continuing improvement in ecological literacy and a continuing appreciation for the value of natural systems in Italy. If that doesn't develop, then the bear's habitat will either be crushed back, or the accumulating development will catch up with it gradually, as is happening here in greater Yellowstone.
YS: But we have some impressive precedents here, in which we were surprised by really big changes in public attitudes. In 1950, who would have predicted that in 30 years most park fisheries would be managed as either catch-and-release or some other very restrictive regulation? People were conditioned to demand dead trout. In 1960, who would have predicted that we would restore fire, or, maybe even more amazing, that we would restore wolves?
SH: What that tells us is we must dream of healthy, sustainable, ecological futures, and we must be convinced that they can happen.
YS: By the way, the Yellowstone Lake crisis, with the discovery of non-native lake trout in the lake, has brought more attention to the importance of the lake's cutthroat trout to the grizzly bear population. We have recently been told that

Yellowstone Lake is the only inland fishery in North America where the native fish are important to a grizzly bear population. Does that statement agree with your experience?

SH: I think that's true. We've got reasonable cutthroat populations in a couple of lakes in Banff, for example, but we have found no evidence of grizzly bears feeding on the spawners. I think it has to do with the overall available biomass in the system. There just isn't enough to really get the bears started on it there, as opposed to here. So yes, I'd agree. I cannot think of another inland fishery situation where fish are as important as they are here. But ironically, this is the last of the great ones. This is the last trout-grizzly bear ecosystem in the lower 48 states.

YS: That seems to add yet another reason to make sure Yellowstone Lake survives in good condition, but situations like our current lake trout crisis on Yellowstone Lake are the sort that can easily lead to despair. We've even heard hard-core, long-time conservationists throw in the towel on this one, and tell us we should just give it up and accept the lake trout. Of course, we don't think we have the legal right to do that, even if we wanted to, but it does suggest the confused mood of the public over what can and cannot be accomplished in saving wild resources.

The Canadian Approach

The point is that we Americans think we have it tough trying to protect the environment, but compared to a lot of other countries, we have some enviable advantages. How is this whole process of conserving rare animals and endangered ecosystems different in Canada? You don't have near the environmental legislation we do to help you accomplish things, do you?

SH: Thank you for asking that. It's a hell of a lot tougher in Canada without an Endangered Species Act. We ultimately have to convince local people that habitat protection, mortality management, development management, and many other initially unpopular things are important enough for people to give up, or at least to modify their short-term resource-development ambitions. It's a lot tougher when you have to fight, in that perspective, day to day, than when you have the overall future of the species as the bottom line for measuring things against. Without an Endangered Species Act, and without a consensus regarding the importance of say, grizzly bears, you don't have the kind of leverage you have here, and there is no baseline against which to develop standards, except possibly population viability.

YS: So who fights the educational battles up there? Is it just the conservation groups who are educating the public? Who speaks for the ecological literacy that we talked about?

SH: It's primarily the conservation groups, and then the national parks.

YS: At Yellowstone's science conference in 1993, Monte Hummel of World Wildlife Fund Canada was one of the keynote speakers, and he explained the Canadian process in terms of building consensus among the interest groups. That seems like the opposite approach from the one taken in the United States, where we seem to move forward through advocacy and confrontation, with one side or the other "winning" each battle, often in court. It is difficult to say which system works best, but it looks as if the Canadians probably know a lot more about consensus building than we do, and more about making do with fewer legal weapons.

SH: Exactly. We have no choice but to build consensus and I'll give you a good example. We've recently founded what we're calling the Eastern Slopes Grizzly Bear Project. It looks at grizzly bears throughout the broader Banff ecosystem, a 22,000-km^2 area with multiple jurisdictions. It's similar to your Interagency Grizzly Bear Committee in scope, but it is not a government-mandated group. It contains representatives from all the jurisdictions that the grizzly bear goes into plus all the major resource–development industries.

It's a hell of a lot tougher in Canada without an Endangered Species Act.

So in contrast to being government-driven, it is much more a grassroots conglomeration of conservation groups, development groups, ranching groups, other resource exploitation groups, and federal and provincial governments. We're bringing all these groups together into a steering committee and trying to build a consensus. We'll look at the map and say, here is where grizzly bears die, here is where their native habitat is, here are the linkages that connect these areas. How can we redesign this whole package to fit the needs of grizzly bears? Of course by taking that approach and using grizzly bears, what we're really doing is buying diversity in large scale for the natural systems of the area.

YS: Monte Hummel stressed that very kind of cooperation and joint public-private leadership. In effect, he said that "We would never expect our government to take the lead." That is a huge difference, a 180-degree difference, from the way we do business in the United States. We simply insist that the federal government take the lead, and we've attempted to empower them to do just that by giving them all these laws—the Endangered Species Act, the National Environmental Policy Act, the National Park Service Act, and many more.

But you raised a more complex question when you spoke of reaching consensus among so many different groups of people. For many people, law and science aren't the central issues at all. The central issues revolve around differing views of the good life, and of the value of nature, and all the emotional, subjective things at stake in these dialogues.

SH: And that is the interesting question: whether the conservation of the future will be driven largely by rational analysis suggesting that it's necessary for our futures, or by some people's emotional, experiential connection with nature.

But I'd like to conduct a little interview here myself, if you don't mind.

YS: That seems fair.

SH: I am curious about how you hope to manage the developments in your regional ecosystem into the future, in terms of the needs of the grizzly bear. Obviously we want the ecosystem to function at the level at which grizzly bear conservation can be a success. But I'm hearing a lot about the major mine [near Cooke

City, Montana] that poses a threat to grizzly bear habitat and other values, and of course there is all the subdivision development in the ecosystem.

YS: And a thousand other threats, with just as many opinions on how serious each of them is.

SH: Right. So how do area managers see this situation, and what are the hopes for preventing the whole greater Yellowstone ecosystem from just being developed to death?

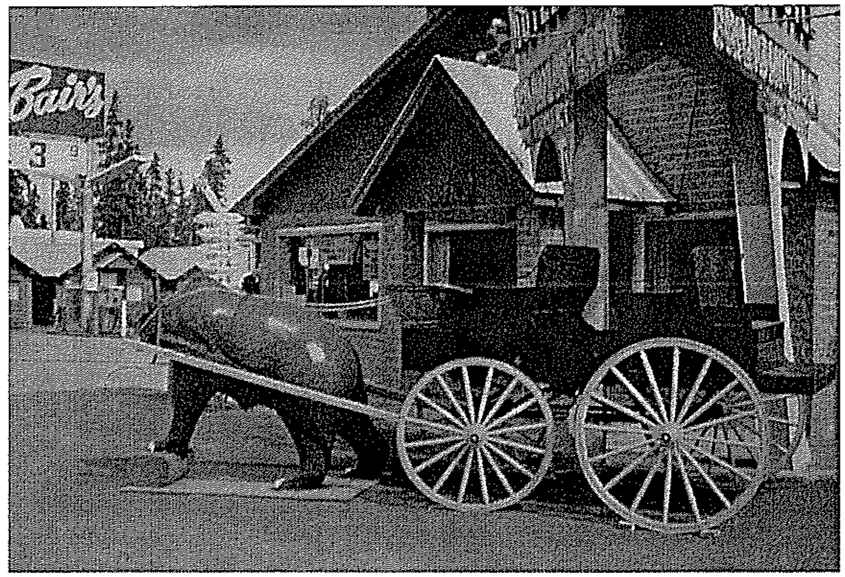
YS: Yellowstone Science doesn't pretend to speak for any of the area's land managers, of course, but there are some obvious elements of the situation that we can review.

For one thing, though we Americans have great laws to help protect bears and the rest of the wild setting, we also have a passionately independent ideal of private property rights. Any time a federal or state agency appears to be even thinking about infringing upon someone's real or imagined private property rights, advocacy groups that normally might not even talk to each other will bunch up to object in unison. Throughout the ecosystem management debates, the rhetoric of the federal managers has sometimes been fairly bold, but it has rarely come near private property issues. That's like discussing religion; it falls outside the realm of possible discussion.

But almost a fifth of the land in greater Yellowstone, depending upon your definition, falls into the category of private land. And the uses of that land already threaten not only grizzly bears, but also wolves and much of the best remaining ungulate winter range. The reality has been that the federal agencies are attempting to honor their mandates to protect grizzly bears and other species and systems solely by doing so on federal lands. Many people would argue that they're failing even there, but like it or not, the federal conservation agencies are pinning their hopes on public lands, and largely ignoring the essential private lands, even though some private landowners are almost willfully destructive of the ecological values that are the region's most important single characteristic.

SH: It seems to be a very big challenge.

YS: It will only be overcome if we experience another of those changes in public



Commercial development is obviously one of the most common threats encroaching upon remaining grizzly bear habitat.

attitudes we talked about earlier. What will have to change is the conceptions of individual people about where they live; until they recognize themselves as members of a bigger and more complex community than their own neighborhood, progress will be slow and painful, if it happens at all.

A big change that has come about because of the greater Yellowstone movement of the past 20 years is that many managers are feeling the necessity of looking beyond their own boundaries, and a growing number of citizens are insisting they do so. Thus we see more interagency coordination, though still not enough, between agencies. Thus we also see our superintendent speaking out on the mine and other ecosystem issues that we believe have significant potential effects on the well-being of the park. Ecosystem management may still be a politically dicey concept, but it's seeping into the works from all directions on the practical level.

The tradition of adversarial relationships is slow to die, but here and there are really promising signs of agencies working not only with each other but also with private landowners to find shared interests and ways to serving everybody's needs. The Greater Yellowstone Coalition and others have been promoting sustainability and community planning, and though we're all only at the beginning of a very long road, it is clear that it's possible to do this right only if we want to badly enough.

SH: I think that we've hit on something that is really important for both countries to consider. There are advantages and disadvantages to the adversarial system of accomplishing things, as it exists in the United States. On the one hand, it has provided you with some excellent strong laws, and on the other hand it has created tremendous divisiveness in the region. There are also advantages and disadvantages of having to make all progress through consensus, the way we do it in Canada. We lack the fundamental legislative mandate forcing us to save clearly defined things, but on the other hand we are getting practiced at hammering out real consensus about how to save what we can all agree we should save.

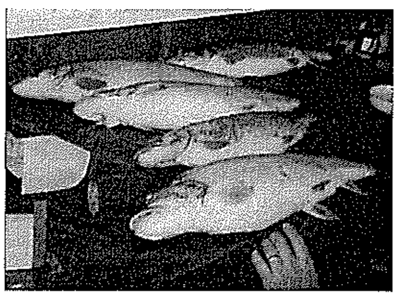
YS: So perhaps what we need is a more creative combination of both systems.

SH: Right. In the future of the greater Yellowstone landscape, you're going to see a lot of things happening on that fifth of the ecosystem that is private. The conservation agencies and conservation groups have the least legal clout on those lands, and that seems like the best place to start working on consensus planning of the sort we have to do all the time in Canada.

Lake Trout Catch Nets Big Ones as Aquatic Threat Looms Larger

The largest remaining inland cutthroat trout population in the world is found in Yellowstone Lake, where it is being preyed upon by nonnative lake trout. Experimental gill–netting continues in an effort to determine the scale of this recently identified threat, and to determine the best means of controlling the lake trout population.

Scale samples indicate that lake trout were illegally introduced at least 16 years ago, but because they usually dwell in deeper water than cutthroat trout, their presence went officially undetected until 1994.



The good news is that most of the fish netted so far in 1996 have come from the West Thumb of Yellowstone Lake. The bad news is that catches include a 32-inch, 12.5 pound mature male lake trout, caught by an angler, and a 33-inch, 20.3 pound female carrying hundreds of eggs. As of July 16, more than 300 lake trout had been caught in gill nets or by anglers this summer.

McIntyre to Serve as Interim Head of Fisheries Staff

Dr. Jack McIntyre, a retired U.S. Forest Service fisheries biologist from Boise, Idaho, has volunteered to serve as the interim head of Yellowstone's fisheries management staff.

Yellowstone has been fortunate to have a U.S. Fish and Wildlife (USFWS) Fisheries Assistance Office located in the park for several decades. However, due to changes in USFWS programs and funding priorities, the fisheries assistance office will close by the end of this fiscal year. One of the USFWS biologists has accepted a transfer and joined the park staff, and the Yellowstone Center for Resources hopes to add more permanent aquatic or fisheries biologists to its ranks in the next few years.

Meanwhile, McIntyre arrived in Yellowstone in July to begin supervising the efforts to control lake trout and maintain other priority programs, such as fluvial Arctic grayling restoration and cutthroat trout population monitoring.

Exotic Plants Reach Record Numbers

The number of exotic plants in the Yellowstone ecosystem has more than doubled in the last ten years, according to Craig McClure, West District Resource Management Coordinator. Known exotic plant species now number 172. Exotic plants are one of the most commonly identified threats to the health of native species in national parks. Some of the exotic plants, such as spotted knapweed, can create monocultures and result in soil erosion, desertification, or reduced forage. Many exotics are not palatable to wildlife.

Dalmatian toadflax (Linaria dalmatica)

The park uses a variety of control techniques, including hand-pulling and approved chemical spraying. The possible use of biological controls is also being evaluated. Biocontrol involves the introduction of parasitic organisms that naturally feed on the exotic plants.

To date, rangers have discovered four species of exotics with biological controls that have not been intentionally introduced: a gall fly, *Urophora affinis,* on spotted knapweed; a flower-head weevil, *Rhynocyllus conicus,* on musk thistle; a beetle, *Brachupterolus pulicarius,* and a weevil, *Gymnetron* spp., both seed-reducing insects, on dalmatian toadflax and on yellow toadflax.

Wolf Dynamics

At least 14 pups were born to four wolf packs (Leopold, Soda Butte, Rose Creek, and Nez Perce) this spring, joining the 31 other wolves known to be living in the Yellowstone ecosystem as of July 15.

Nine wolves have died since the reintroduction program began in January 1995. The latest fatalities include the second to result from collision with a truck (the alpha female of the Chief Joseph pack) and two deaths that may have resulted from interactions between packs.

On May 20, the radio collar on the alpha male of the Crystal Creek pack gave off a mortality signal. The dead wolf, found near what was believed to have been the pack's den site in the Lamar Valley, had puncture wounds on its hind legs. Biologists believe he may have been killed by the Druid Peak pack, which has frequented the northern portion of the Lamar Valley and the upper Slough Creek drainage since its release in April. The two remaining members of the Crystal Creek pack are still in the Lamar Valley.

The Rose Creek pack, which was released in 1995, denned along lower Slough Creek, and on June 18 was observed fighting there with the Druid Peak pack. Three days later, a radio signal indicated the mortality of a Rose Creek yearling male. Biologists speculate the wolf, which was in excellent condition at the time of his death, may have also died of wounds caused in the encounter between packs. Both carcasses have been sent to a forensics lab to determine the exact cause of death.

Members of two packs have been captured and are being temporarily penned in the park in response to rancher concerns about livestock predation. This includes all seven wolves in the Soda Butte pack, which denned on private land in west Rosebud Creek near the Custer National Forest, and two yearlings from the Nez Perce pack, which has ranged apart since its release in April. As of mid-July, efforts were underway to catch the Nez Perce alpha female and four pups seen with her. A fifth pup was wounded in a trap set for the adult wolf and is under veterinary care. This summer, eight sheep deaths have been officially attributed to wolf predation, and it's believed that Nez Perce pack members were responsible.

Inside Yellowstone National Park, visitors again enjoyed wolf watching opportunities, especially in the Slough Creek area during elk calving season in June.

"Greening of Yellowstone" Workshop Scheduled for October

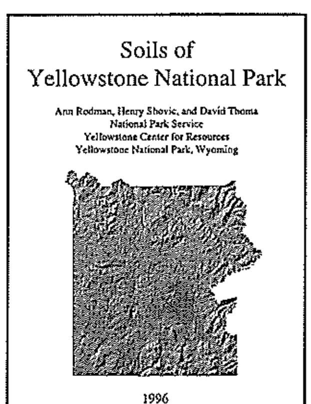
The *Greening of Yellowstone Workshop: Great Ideas for the Next 125 Years for the Park and its Neighbors* will be held October 16-18, 1996, at the West Yellowstone Conference Center. The workshop's goal is to foster more sustainable use of resources in the park and surrounding region, and to promote partnerships to address more efficient energy sources, transportation, waste and water management, and use of biodegradable and recyclable materials.

The workshop is jointly sponsored by the National Park Service, the Montana Department of Environmental Quality, the U.S. Department of Energy, Global Environmental Options, and a variety of public and private interests. The registration fee is $125 per person, including meals and workshop proceedings. Group discounts are available. For more information contact Holly Long, Greening Workshop, Yellowstone National Park, P.O. Box 168, Yellowstone National Park, Wyoming 82190,
(307) 344–2324. Fax (307) 344–2356; email: holly_long@nps.gov.

Proceedings from *The Ecological Implications of Fire in Greater Yellowstone: the Second Biennial Conference on the Greater Yellowstone Ecosystem* are now available. Copies are being sent to all conference registrants. Additional copies may be purchased for $24.95 (includes tax, shipping, and handling) by contacting Jason Greenlee, International Association of Wildland Fire, P.O. Box 328, 103 East Main Street, Fairfield, WA 99102–0328. (800) 697-3443 Fax (509) 283–2264; email: jgreenlee@igc.apc.org.

Yellowstone's Soil Survey Completed

After eight years of data collection, ground-truthing, and analysis, Yellowstone's soil survey has been completed. The project, headed by Dr. Henry Shovic under a cooperative agreement with the Gallatin National Forest, has resulted in the printing of maps and two documents, entitled *Soils of Yellowstone National Park* and *Landforms and Associated Surficial Materials of Yellowstone National Park.* The reports will be distributed to park staff, cooperators, and Yellowstone's research library; limited copies may be available by contacting Ann Rodman, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, Wyoming 82190, (307) 344–2216.


Soils of
Yellowstone National Park

Ann Rodman, Henry Shovic, and David Thoma
National Park Service
Yellowstone Center for Resources
Yellowstone National Park, Wyoming

1996

Obsidian Cliff Becomes a National Historic Landmark

On May 6, 1996, the Obsidian Cliff archeological site between Norris and Mammoth was approved as a National Historic Landmark. Only a few of the historic properties with national significance, as defined for the National Register of Historic Places, are selected for this honor; approval of Obsidian Cliff by the Landmarks Committee took nine years. The Register is a listing of important archeological sites, buildings and locations that have historic or cultural values.

There are several features that qualified Obsidian Cliff National Historic Landmark as a landmark and that make it unique. For nearly 12,000 years, native peoples engaged in the mining and production of stone tools made of obsidian, a volcanic stone commonly found in Yellowstone. Prehistoric peoples traded these tools and raw materials around the continent. As raw material, obsidian could be worked into tools sharper than modern surgical scalpels, and it could be transformed into jewel-like precious objects that continue today to be revered as art and symbols of power and wealth.

One of the most renowned sources of obsidian was Obsidian Cliff. The ancient societies who occupied the area were hunters and gatherers, and the societies to which obsidian was traded varied substantially in economy, settlement, and sociopolitical and ceremonial organization over time and space. Obsidian Cliff includes intact mining features, workshops, and campsites of what can be called one of the first industrial areas by people in North America.

Obsidian Cliff also played a major role in the application and development of techniques for geochemical fingerprinting and dating of obsidian. These techniques, which analyze elemental components of the rock, have subsequently been used to study other types of stone that were culturally modified and traded. Obsidian-hydration dating was introduced by geochemists to American archeology as a new chronometric method with the initial work based on Obsidian Cliff obsidian. These sourcing and dating analyses are now routinely used in American archeology.